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Description

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WO 02/046486 (13.06.2002 Gazette 2002/24) Care, environ nental problems dosed by automobiles have lead to a manage in meds for a re-• ASO, Toshimitsu, (84) Designated Contracting States: c/o Nagoya Works Nippon Steel Co. AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU workability has been remarded (qu) 3838-376 Inchies been villaking a composite structure, such as a felial (OTOMA) or other MC NL PT SE TRY Work and those state of a state of a fertite-baints structure, and those having a substantially single-prace leading and ward ward ward or fe (30) Priority: 07.12.2000 JP 2000372460 9th a result of the page 2000372461 and to the page 3.07.12.2000 JP 2000372460 and to the page 3.07.12.2000 JP 2000372461 and to the page 3.07.12.2000 JP 200037240 and to the page 3.07.12.2000 JP 200037240 and to the page 3.07.12.2000 And to the page 3.07.12.2000 And to the page 3.07.1 is stuc Tokal-shi, Aichi 476-8686 (JP) ellenette met net adt al. [2000] bore expand coultry This ABNTRAG & 201820V With a factor of the components, where a process of the components, where a process of the components where a process of the components where a process of the components of the componen [0004] In high strength hat rolled steel p(30) hehand 7675 word expandability and ductify are like (40) 1708-1001 own dictory to each other. Specifically reducing the difference in hardness between ferrite and be nite is one means to (72) Inventors: on the hardness to the however, matching the hardness to the however, matching the hardness to the however, matching the however, matching the however, and the however, matching the however, and improving the core expendicibility in the femile-camite structure. In this of hard balotte results in significantly deteriorated ductility, while matching the hardness to that of soft far is in South (Navyorith ADA) c/o Nagoya Works Ninda Steel Co. do Instruction to the lack of strength, a lar je smount of property strength or compensation for the lack of strength and the lack of the lac to strengther the stop plate. As a result, the ductility is lowered, Japanese Patent Laid-Op(qu) 3888-374 inches in a strengther the strengther than the ductility is lowered. 1804/25/1991 disclose steel plates having a structure composed maintly of baintle. 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The steel plate according to move those of the steel plate according to the steel plate according to the steel plate according to the steel plate wherein in the steel plate wherein in the steel plate wherein in the steel plate according to the steel plate wherein in the steel plate wherein in the steel plate wherein t plate having the above composition, the steel plate has monthly without steel plate having the auditive without steel plate has a ferrite-baingte, duplex steel structure, in which the population of hat is in to one structure with the first use (see) of the first use (2 μm is not less than 80%, and has a strength of not less niture to 1000 not 200 1000 control of one almost strength of not less nitures. than 690 N/mm2. The steel plate according to the third idebneural word was more a substance of evorces. 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steel having the above composition, the contents of C, Si, Mn, Ti and Nb satisfying a requirement represented

Description

[BACKGROUND OF THE INVENTION]

Technical Field

[0001] The present invention relates to high strength hot rolled steel plates which are intended for use, for example, in automobile under-carriage components mainly produced by pressing, have a thickness of about 1.0 to 6.0 mm, have a strength of not less than 690 N/mm², and possess excellent bore expandability and ductility, and a process for SENGINEER STATE producing the same.

Background Art

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[0002] In recent years, environmental problems posed by automobiles have lead to an increase in needs for a reduction in weight of car bodies and a reduction in cost by one-piece molding of components, for improving fuel consumption. To meet these needs, the development of high strength hot rolled steel plates possessing excellent press workability has been forwarded. Well-known conventional high strength hot rolled steel plates for such working include those having a composite structure, such as a ferrite-martensite structure or a ferrite-balnite structure, and those having a substantially single-phase structure composed mainly of bainite or ferrite.

[0003] In the ferrite-martensite structure, however, cracking occurs as a result of the formation of microvoids around martensite from an early stage of deformation, and, thus, the ferrite-martensite structure suffers from a problem of poor bore expandability. This renders steel plates having a ferrite-martensite structure unsuitable for use in applications, such as under-carriage components, where a high level of bore expandability is required. [0004] In high strength hot rolled steel plates, it is known that bore expandability and ductility are likely to be contra-

dictory to each other. Specifically, reducing the difference in hardness between ferrite and bainite is one means for improving the bore expandability in the ferrite-bainite structure. In this case, however, matching the hardness to that of hard bainite results in significantly deteriorated ductility, while matching the hardness to that of soft ferrite results in unsatisfactory strength. For compensation for the lack of strength, a large amount of precipitates should be dispersed to strengthen the steel plate. As a result, the ductility is lowered. Japanese Patent Laid-Open Nos. 88125/1992 and 180426/1991 disclose steel plates having a structure composed mainly of bainite. Due to the nature of the structure composed mainly of bainite, however, the amount of the soft ferrite phase is so small that the ductility is poor, although, the bore expandability is excellent. Japanese Patent Laid-Open Nos. 172924/1994 and 11382/1995 disclose steel plates having a structure composed mainly of ferrite. These steel plates possess excellent bore expandability. Since, however, hard carbides are precipitated for ensuring strength, here again, the ductility is poor.

[0005] Japanese Patent Laid-Open No. 200351/1994 discloses a steel plate having a ferrite-bainite structure which possesses excellent bore expandability and ductility, and Japanese Patent Laid-Open No. 293910/1994 discloses a production process of a steel plate having a combination of good bore expandability with good ductility wherein twostage cooling is adopted to regulate the proportion of ferrite. However, for example, a further reduction in weight of automobiles and increased complexity of components have led to a demand for a higher level of bore expandability and automobiles and increased complexity of components have led to a demand for a higher level of bore expandability and a second components have led to a demand for a higher level of bore expandability. and a higher level of ductility, and a high level of workability and a high level of strength; which cannot be satisfied by the above conventional techniques, are required of steel plates and sheets; the leader to distinct the chiral inflances costs. gmangle creat compositive groups and artist to 18% and assertion of the control o

[SUMMARY OF THE INVENTION]

object of the present invention to provide a high strength hot rolled steel plate, which can prevent a deterioration in 9 13 3 16 16 bore expandability and ductility involved in an increase in strength to not less than 690 N/mm² and, despite high and success than 690 N/mm² and, despite high and success that success the success to the success that success the success to the success that success the success to the success that success the success that strength, possesses a high level of bore expandability and a high level of ductility, and a process for producing the sonsisti kataba olitkii in FD. Siment osstota graunymos steel plate.

[0007] As described above, in high strength hot rolled steel plates, it is well known that bore expandability and ductility and ductility are likely to be contradictory to each other. The present inventors have made extensive and intensive studies with a second contradictory to each other. view to attaining the above object of the present invention and, as a result, have found that spheroidizing grains in the second or ferrite-bainite steel as much as possible can improve the ductility without sacrificing the bore expandability. This had led to the completion of the first aspect of the present invention. That is, in the first aspect of the present invention, the above object of the present invention has been attained by drawing attention, in a ferrite-bainite steel, to ferrite for enhancing the ductility and to precipitates of TIC and/or NbC for ensuring the strength; satisfactorily spheroidizing สดุทศไทย a cock ตูนักสามารถเป็นสู่โดย และ เล่าที่คือ อไทย์ คิดภ กลูย (a และอย การ) การ () การ () และ () และ () the strength.

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100081 Thus, according to a first aspect of the present invention, there is provided a high strength hot rolled steel (Solar of plate having excellent bore expandability and ductility, comprising a steel comprising, by mass, 0.01 to 0.15% of carbon; 0.30 to 2.00% of silicon; 0.50 to 3.00% of manganese; phosphorus ≤ 0.03%; sulfur ≤ 0.005%; 0.01 to 0.50% of titanium ct. silicon and/or 0.01 to 0.05% of nioblum; and the balance consisting of iron and unavoidable impurities, not less than 80% of all grains being accounted for by grains having a ratio (ds/dl) of minor axis (ds) to major axis (dl) of not less than 0.10 grains to the day of the day o said steel plate having a steel structure comprising not less than 80% of ferrite and the balance consisting of bainite. the steel plate having a strength of not less than 690 N/mm². Stein colonical compection of high strength hours lad tree, when [0009] The present inventors have further found that, in a ferrite-balnite steel, maximizing the proportion of ferrite grains having a given or larger grain diameter can improve the ductility without sacrificing the bore expandability. This is not a factor of the bore expandability. This is not a factor of the bore expandability. has led to the completion of the second aspect of the present invention. That is, in the second aspect of the present of the p for enhancing the ductility and to precipitates of TiC and/or NbC for ensuring the strength, satisfactorily growing ferrite grains to improve the ductility without sacrificing the bore expandability and then producing precipitates to ensure the strength. (daystorial trethes offsearth reviewed vit. of the control of collection of the second aspect of the present invention, there is provided a high strength hot rolled. steel plate having excellent bore expandability and ductility, comprising, by mass, 0.01 to 0.15% of carbon; 0.30 to 2.00% of silicon; 0.50 to 3.00% of manganese; phosphorus ≤ 0.03%; sulfur ≤ 0.005%; 0.01 to 0.50% of titanium and/ or 0.01 to 0.05% of niobium; and the balance consisting of iron and unavoidable impurities, said steel plate having a sone led not less than 80%, said steel plate having a strength of not less than 690 N/mm² pl of not less than 770 N/mm2, increasing the diameter of ferrite grains is effective for improving the ductility. This has led to the completion of the third aspect of the present invention. That is, the third aspect of the present invention has been attained by drawing attention, in a ferrite-bainite steel, to ferrite for enhancing the ductility and to precipitates of TiC and/or NbC for ensuring the strength and finding a relational expression for satisfactorily growing ferrite grains to end possible. improve the ductility without sacrificing the bore expandability and then producing precipitates to ensure the strength, to assistance. [0012] Thus, according to the third aspect of the present invention, there is provided a high strength hot rolled steel 171601 plate having excellent bore expandability and ductility, comprising a steel comprising, by mass, 0.01 to 0.15% of carbon; of carbon of the steel comprising a steel comprising to the steel comprisin and/or 0.01 to 0.05% of note in seasons and unavoidable impurities, the contents of carbon to 0.05% of note in seasons and unavoidable impurities, the contents of carbon to 1.00.05% of note in seasons and unavoidable impurities, the contents of carbon to 1.00.05% of note in seasons and the balance consisting of iron and unavoidable impurities, the contents of carbon to 1.00.05% of note in seasons and the balance consisting of iron and unavoidable impurities, the contents of carbon to 1.00.05% of note in seasons and the balance consisting of iron and unavoidable impurities, the contents of carbon to 1.00.05% of note in the carbon to 1.00.05% of note (C), silicon (Si), manganese (Mn), titanium (Ti), and niobium (Nb), satisfying a requirement represented by formula: vices said of resilizing a combination of the strangth of not lease two 800 N/mm² with a high level of bore expandability and a nigh level of ductility. The manganese cr([%nM] 00 Pe [%i2] 00 fi⊊[%2] 08¥e 719)≦r£f100 to 1 50% from the vieurpoint of affectively realizing the combination of the shear, that the than 880 M/mm² with the high level of bore expand softly and the high level of dustility $(50.0)^{-2.0}$, $(50.0)^{-2.0}$ (SV($(50.0)^{-2.0}$) $(50.0)^{-2.0}$ Programms (P) is dissolved in territore form a softly which detendants the duality of the hot roller. said steel plate having a strength of not less than 770 N/mm².

Jayo 6 roll error to a strength of not less than 570 N/mm².

Jayo 6 roll error to a strength of not less than 570 N/mm².

These high strength hot rolled steel plates having excellent bore expandability and ductility can be produced. by a production process comprising the steps of subjecting the steel having said chemical composition to hot rolling in such a manner that the rolling termination temperature is Ar₃ transformation temperature to 950°C; subsequently, cooling the hot rolled steel plate to 650 to 800°C, at a cooling rate of not less than 20°C/sec.; then air cooling the steel plate for 2 to 15 sec.; further cooling the steel plate to 350 to 600°C at a cooling rate of not less than 20°C/sec.; and colling the steel plate is a notibble of the month one made such as the second of unionities of become as the colling the steel plate is a notibble of the month of the second of the se [BRIEF DESCRIPTION OF THE DRAWINGS] or understand the second of the second process of th 0.20% with the nichlan content being not more than an are-[0014] -2000 M. Concert and to count electronic (REModeurs discrete to the second for equivaling the form of subits and use Fig. 1 is a scatter diagram showing a correlation between the proportion of grains of ds/d > 0.1 and the elongation for steels according to the first aspect of the present invention and comparative steels.

Fig. 2 is a scatter diagram showing a correlation between the proportion of the first aspect of the present invention and comparative steels.

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for steels according to the third aspect of the present invention and comparative steels; and Fig. 5 is a scatter diagram showing a correlation between the value obtained by calculation formula and the elongation for steels according to the third aspect of the present invention and comparative steels.

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[DETAILED DESCRIPTION OF THE INVENTION] ใช้ท**ัดเ**รียนการ และขาง เป็นเป็นที่ การ

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Basic chemical composition of high strength hot rolled steel plate

[0015] In the present invention, the content of carbon (C) in the high strength hot rolled steel plate is 0.01 to 0.15%; preferably 0.01 to 0.08%. Carbon is an element necessary for precipitating carbides to ensure strength. When the carbon content is less than 0.01%, it is difficult to ensure desired strength. On the other hand, when the carbon content exceeds 0.15%, the ductility is significantly lowered. In particular, the addition of carbon is effective for realizing a strength of not less than 980 N/mm². From the viewpoint of providing a combination of the strength of not less than 980 N/mm² with a high level of bore expandability and a high level of ductility, however, the carbon content is preferably and the state of the state of $\Delta t = \Delta t_1 + \mu t_2 = 1$ brought to not more than 0.08%. 10 f 10 50 50 51 119 5 77 1

[0016] Silicon (Si) is one of the most important elements in the present invention and is important for suppressing the formation of harmful carbides to bring the structure to a composite structure composed mainly of ferrite with the balance consisting of balinite, and, further, the addition of slicon can provide a combination of strength with ductility. The addition of silicon in an amount of not less than 0.3% is necessary for attaining this effect. Increasing the amount of silicon added, however, deteriorates chemical conversion treatment and, in addition, deteriorates spot weldability. For this reason, the upper limit of the amount of silicon added is 2.0%. In particular, the addition of silicon is effective for realizing a strength of not less than 980 N/mm². In order to realize a combination of the strength of not less than 980 N/mm² with a high level of bore expandability and a high level of ductility, however, the silicon content is preferably 2000 to the silicon content is p not more than 1.5%. A silicon content in the range of 0.9 to 1.2% is particularly preferred from the viewpoint of effectively and the content in the range of 0.9 to 1.2% is particularly preferred from the viewpoint of effectively and the content in the range of 0.9 to 1.2% is particularly preferred from the viewpoint of effectively and the content in the range of 0.9 to 1.2% is particularly preferred from the viewpoint of effectively and the content in the range of 0.9 to 1.2% is particularly preferred from the viewpoint of effectively and the content in the range of 0.9 to 1.2% is particularly preferred from the viewpoint of effectively and the content in the range of 0.9 to 1.2% is particularly preferred from the viewpoint of effectively and the content in th realizing the combination of the strength of not less than 980 N/mm² with the high level of bore expandability and the high level of ductility. ម្រង់ នៅក្នុងប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប្រការប ି । ନାମ ବ୍ୟାସ ନିର୍ମ୍ଦ ପ୍ରଥମଣ ହେଉଁ ବେଶ୍ୱର ବର୍ଷ ଓ । ଅଧି ବ୍ୟୁଷ୍ଟ ଅଧି ଅଧି ହେଉଁ । ପ୍ରଥମ ବ୍ୟୁଷ୍ଟ । ଓ । ଅଧିକ୍ରଣ

[0017] Manganese (Mn) is one of elements important to the present invention and is necessary for ensuring the strength. To this end, the addition of manganese in an amount of not less than 0.50% is necessary. The addition of manganese in a large amount exceeding 3.0%, however, is likely to cause microsegregation and macrosegregation; which deteriorate the bore expandability. In particular, in order to realize a strength of not less than 980 N/mm², the addition of manganese is effective. The manganese content, however, is preferably not more than 2.5% from the viewpoint of realizing a combination of the strength of not less than 980 N/mm² with a high level of bore expandability and a high level of ductility. The manganese content is particularly preferably in the range of 1.00 to 1.50% from the viewpoint of effectively realizing the combination of the strength of not less than 980 N/mm² with the high level of bore expandability and the high level of ductility.

[0018] Phosphorus (P) is dissolved in ferrite to form a solid solution which deteriorates the ductility of the hot rolled steel plate. For this reason, the content of phosphorus is limited to not more than 0.03%. Sulfur (S) forms MnS which functions as the origin of a failure and significantly deteriorates the bore expandability and the ductility. Therefore, the content of sulfur is limited to not more than 0.005%.

[0019] Titanium (TI) and niobium (Nb) each are also one of the most important elements in the present invention and are useful for precipitating fine carbides, such as TIC and NbC, to ensure the strength. To this end, the addition of 0.0500 (100 to 100 to 10 to 0.50% of thanlum and/or 0.01 to 0.05% of nioblum is necessary. When the thanlum content is less than 0.05% and the niobium content is less than 0.01%, it is difficult to ensure the strength. On the other hand, when the thanium content exceeds 0.50% and/or the niobium content exceeds 0.05%, the amount of the precipitate is so large that the ductility is deteriorated. In particular, in order to realize a strength of not less than 980 N/mm², the addition of titanium and niobium is effective. From the viewpoint of realizing a combination of the strength of not less than 980 N/mm2 with a 30 KB 801 high level of bore expandability and a high level of ductility, however, the titanium content is preferably not more than 0.20% with the niobium content being not more than 0.04%.

[0020] Calcium and rare earth elements (REMs) are elements that are useful for regulating the form of sulfide inclusions to improve the bore expandability. In order to attain significant form regulation effect, the addition of not less than 0.0005% of at least one member selected from calcium and REMs is preferred. On the other hand, the addition of an excessively large amount of calcium and REMs leads to coarsening of sulfide inclusions, deteriorates the cleanness. and lowers the ductility. This further leads to an increase in cost. For the above reason, the upper limit of the content of calcium and REMs is 0.01%. acts with mean to him continued matrix oils to

High strength hot rolled steel plate according to first embodiment

e cal places for circle accept for the block and accept for the control of the co [0021] The ratio (ds/dl) of the minor axis (ds) to the major axis (dl) in the grains is an index of the level of grain growth

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and is one of the most important indexes in the first embodiment of the present invention. In order to simultaneously, at 33 hours realize a high level of bore expandability and a high level of ductility, grains should be grown to a minor axis/major axis ratio (ds/dl) of not less than 0.1. When the minor axis/major axis ratio in the grains is less than 0.1, grains are flat and are not satisfactorily recovered grains. This is causative of a deterioration in ductility. Not less than 80% of all the grains. should be accounted for by grains having this minor axis/major axis ratio. When the above proportion is less than 80%, 32 serior of a the ductility is deteriorated. In this case, when the tensile strength is not less than 690 N/mm2 a high level of ductility conditions again. and a high level of bore expandability cannot be simultaneously realized, Fig. 1 is a diagram showing the correlation and a high level of bore expandability cannot be simultaneously realized. between the proportion of grains having minor axis/major axis ratio ≥ 0.1 and the elongation in high strength hot rolled steel plates having a tensile strength of 780 to 820 N/mm² and a λ value (bore expansion or enlargement value) of 1780 to 820 N/mm² and a λ value (bore expansion or enlargement value) of 1780 to 820 N/mm² and a λ value (bore expansion or enlargement value). 100 to 115. As can be seen from Fig. 1, when the proportion is less than 80%, the ductility is unfavorably deteriorated, at the anistro Accordingly, in the first embodiment of the present invention, in order to simultaneously realize a high level of bore expandability and a high level of ductility, the proportion of grains having minor axis/major axis, ratio ≥ 0.1 in all the minor axis/major axis, ratio ≥ 0.1 in a single properties and minor axis/major axis, ratio ≥ 0.1 in a single properties axis, and the minor axis/major axis, ratio ≥ 0.1 in a single properties axis, and the minor axis/major axis, ratio ≥ 0.1 in a single properties axis, and the minor axis, and the min grains should be not less than 80%. Preferably, the proportion of grains having minor axis/major axis ratio ≥ 0.2 is not less than 80% from the viewpoint of attaining more significant effect. Less than 80% from the viewpoint of attaining more significant effect. Less than 80% from the viewpoint of attaining more significant effect. Less than 80% from the viewpoint of attaining more significant effect. Les participations of attaining more expandability and ductility according to the present invention may be produced by hot rolling a semi-finished steel product containing the above constituents, such as a slab. In this case, the steel structure in the high strength hot rolled steel plate should be a duplex structure comprising not less than 80% of ferrite with the balance consisting of bainite. When the amount of ferrite is less than 80% of service is less than 80% of service with the balance consisting of bainite. When the amount of ferrite is less than 80% of service with the balance consisting of bainite. the ductility is significantly deteriorated and, thus, the amount of femite in the femite-bainite structure should be not less, in spelounts [0028] The steel place according to the fourth embodement has both the features of the first embodiment and the features of the second embodiment. Specifically, Prof. of the second embodiments also can improve the High strength hot rolled, steel plate according to second embodiment intention of being bound by any particular theory, twentsure as a fine homogenization of the structure and a reduction [0023] The diameter of ferrite grains is one of the most important indexes in this embodiment. As a result of extensive and intensive studies conducted by the present inventors, it have been found that, when the percentage area of ferrite to be a serie having a grain diameter of not less than 2 um is not less than 80%, both the bore expandability and the ductility are a gniver excellent. Specifically, as shown in Fig. 2 (an example of a high strength hot rolled steel plate having a tensile strength, corepisates) of 780 to 820,N/mm2 and a \(\lambda\) value of \(\lambda\) (0.115), when the proportion of ferrite grains having a diameter of \(\text{not.less}\) case and off than 2 µm is not less than 80%, the steel plates have a high level of ductility. When the grain diameter is less than 2 is in the steel plates have a high level of ductility. When the grain diameter is less than 2 is in the steel plates have a high level of ductility. When the grain diameter is less than 2 is in the steel plates have a high level of ductility. μm, grains are not satisfactorily recovered, grown grains. This is causative of a deterioration in ductility. Accordingly, in the second embodiment of the present invention, the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of ferrite grains having a diameter of not less than the proportion of t 2 µm should be not less than 80% from the viewpoint of simultaneously realizing good bore expandability and good ductility. Preferably, the proportion of ferrite grains having a diameter of not less than 3 um is not less than 80% for 19600] attaining more significant effect. The grain diameter may be determined by converting the area of each grain into equivalent circle diameter sest induced as the steel structure of the steel structure in the high strength hot rolled steel plate is comprised of ferrite and baintie. Here since the structure in the high strength hot rolled steel plate is comprised of ferrite and baintie. Here since the structure in the high strength hot rolled steel plate is comprised of ferrite and baintie. Here since the structure in the steel structure, the steel structure, the steel structure in the steel structure. structure is a ferrite-bainite duplex steel structure having a ferrite content of not less than 80%. For example, the steel structure according to the present invention may be a ferrite-bainite structure comprising not less than 80% of ferrite having a grain diameter of not less than 2 µm with the balance consisting of ferrite having a grain diameter of less than 2 µm and bainite, or a ferrite-bainite structure comprising not less than 80% of ferrite having a grain diameter of not less than 2 μm with the balance consisting of bainite only. The reason why the content of the bainite should be not more than 20% is that the presence of bainite in an amount of more than 20% increases the level of a deterioration in ductility. [0tc.1] The step, plate eccording to this lifth the cheep pean be featured of the first embodimont and litic

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High strength hot rolled steel plate according to third embodiment Catalogs of the Child embeddinger. Specification to

mo bini cht film nomibodime tatil oht fo notronderne de land op loc off privaram in evitoding superibodine [0025] In the third embodiment of the present invention, the contents of carbon (C), silicon (Si), manganese (Mn) of the present invention, the contents of carbon (C), silicon (Si), manganese (Mn) of translation (Ti), and niobjum (Nb) should satisfy a requirement represented by formula:

of the termation of alloy carbides intrantaged to the country line above requirement for the form of termination ant to reductinegome 115t (917 tr480 [C%] tr100 [Si%] a 100 [Mn%]) - of brund gried to neither on as eacht of the structure and a regulation in the number of only is a first of a first improving the bore expandition to be is one significant avoids on $y(790] \times ([Ti6] + [Nb\%]/2)^{0.05}) \le 235$ and a financial restriction in the first of terms of the first of terms carried the first of terms of terms of terms.

[0026] The left term of the formula, i.e., (917 - 480 [C%] + 100 [Si%] - 100 [Mn%]), exhibits easiness in the formation of ferrite, while the right term of the formula, i.e., (790 x ([Ti%] + [Nb%]/2)0.05), exhibits easiness in the precipitation of carbides, such as TiC and NbC. In order to preferentially produce ferrite to grow ferrite grains, the precipitation of

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carbides having the effect of inhibiting the grown of grains should be suppressed. To this end, the value obtained by the calculation formula should be not less than 115. On the other hand, when the precipitation of carbides is excessively suppressed, carbon in solid solution is enriched in bainité to increase the hardness of bainite. This increases the difference in hardness between ferrite and bainite and consequently deteriorates the bore expandability. For this reason, the value obtained by the calculation formula should be brought to not more than 235 for effectively precipitating car-ាសារសេស ពីស ២ ៤ ខាន់ទៅការ ២៧ ភេស ២៩៣ ១៩៣ សំព័ន្ធ សំព័ន្ធ សំព័ន្ធ មាននេះ ប្រើបានប្រើបាន bides to improve the bore expandability.

[0027] The high strength hot rolled steel plate possessing excellent bore expandability and ductility according to the present invention may be produced by hot rolling a semi-finished steel product containing the above constituents, such as a slab. In this case, the steel structure in the high strength hot rolled steel plate should be a duplex structure comprising not less than 80% of ferrite and the balance consisting of bainite. When the amount of ferrite is less than 80%, the ductility is significantly deteriorated and, thus, the amount of ferrite in the ferrite bainite structure should be not less than 80%. In this connection, it should be noted that a minor amount of residual γ is sometimes contained in bainite. មិទី៩១៩១ ដែល ខេត្ត ស្រ ១៩៩៣ ዜተጠቁ መሟተ

High strength hot rolled steel plate according to fourth embodiment पुर इतिपन प्रश्नापश्चनात्र अस्ति। स्टब्स्

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[0028] According to the fourth embodiment, which is a preferred embodiment of the present invention, preferably, not less than 80% of all the grains are accounted for by grains having a minor axis (ds) to major axis (dl) ratio (ds/dl) of not less than 0:1, the strength is not less than 690 N/mm², and, further, the steel structure is a ferrite-ballite duplex structure in which the proportion of ferrite having a grain diameter of not less than 2 hm is not less than 80%. However, a viscous contraction of ferrite having a grain diameter of not less than 2 hm is not less than 80%. [0029] The steel plate according to the fourth embodiment has both the features of the first embodiment and the features of the second embodiment. Specifically, each of the first and second embodiments also can improve the ductility. A combination of these embodiments, however, can further improve the bore expandability. While there is no threats that intention of being bound by any particular theory, two measures, i.e., the homogenization of the structure and a reduction in the number of origins of cracks, are effective for improving the bore expandability, and the interface of the ferrite phase and the bainite phase can be reduced by regulating both the aspect ratio (ds/dl) and the proportion of femite then still be having a grain diameter of not less than 2 µm so as to fall within the above respective predetermined ranges. It is considered that the above fact can reduce the number of origins of cracks at the time of bore expanding to improve the bore expandability. This function can also be realized by the first of second embodiment. The fourth embodiment, 38 or 68 14 which is a combination of the first and second embodiments, can provide the most effective function: 3 1000 and 1000 and

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High strength hot rolled steel plate according to fifth embodiment thegard and moderate tracers and the second 2) time crossed for no costerioric CCD. From the vicaspoint of other incounty medicing good and experience and time

[0030] According to the fifth embodiment, which is a preferred embodiment of the present invention, in the steel plate having the above basic chemical composition, preferably, not less than 80% of all the grains is accounted for by grains having a minor axis (ds) to major axis (dl) ratio (ds/dl) of not less than 0.1, the steel structure comprises not less than 80% of ferrite and the balance consisting of baintie, the strength is not less than 770 N/mm², and, in addition, the contents of carbon (C), sillicon (Si), manganese (Mn); thanlum (Ti), and nioblum (Nb) satisfy a requirement represented the salture by formula:

eth course according to the present invention may be a fermorbail the structure demonstrig not less than 80% of tente e murgia grale di crene et not le caltur la jum a du tras patinos oppolistog of fouto o eveng a grufe dismoveror toto dism ton to recorded this of 115 ≤ (917/4 480-[C%] + (1.00 [SI%] ± (1.00 [Mn]%]); or other the other tree of the contraction of the าอก ลิซ พบอฟร เมื่นแล้ว เที่ ได้ "ถามีก่อง จาวัวรูปขาดของสายที่ได้เกิด ย่าเกิดได้ขาย ยุก teler ขอ ๑๐๓ . คิซ ดีที่ได้ว่า ยอยู่ 2 กอาที ของมี กากต่องการเรียบ แล้ว tevel อวี **(790 x ([T]%] ∓ [Nb%]/2)^{0,05}) ≤:235**เม และสายสมาชาวิธ ของจอบสด ดัว ภาณ เกิดใช้ ตองที่ จากก custille

[0031] The steel plate according to this fifth embodiment has both the features of the first embodiment and the features of the third embodiment. Specifically, the first embodiment is effective in improving the ductility, while the thirds make dollar embodiment is effective in improving the bore expandability. A combination of the first embodiment with the third embodiment, however, can provide a synergistic effect on an improvement in ductility and an improvement in bore expandability. Further, when the chemical composition falls within the range represented by the above formula, the control (1) of the formation of alloy carbides advantageously facilitates satisfying the above requirement for the form of ferrite. While there is no intention of being bound by any particular theory; two measures, i.e., the homogenization of the structure and a reduction in the number of origins of cracks, are effective for improving the bore expandability. It is considered that an improvement in the former, i.e., homogenization of the structure, by the above formula and an improvement in the latter, i.e., a reduction in the number of origins of cracks, by controlling the form of ferrite can provide a synergistic effect on an improvement in bore expandability.

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นอบ อเท ระ ฮออมดากร คุณกษายา มีกรุษาที่ (of leming with the right trans of the formula, t.c. (790 is (1784) - [NSF-]MIPPE), authorise enginees in the precipation of octordes, auch ut 19.0 und Rub in order to protentially produce levine to craft forthe grains, the procup abor of

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High strength hot rolled steel plate according to sixth embodiment

the radial stability in applicance (38 colors of the table relief to end of any cooling rate of not less than 20°C/sectiand to 15 sec. Further, the air-cocledisted place is coched to

[0032] According to the sixth embodiment, which is a preferred embodiment of the present invention, in the steel pation double plate having the above basic chemical composition, preferably, the steel structure is a ferrite bainite duplex structure has requered in which the proportion of ferrite having a grain diameter of not less than 2 µm is not less than 80%, the strength is not included. less than 770 N/mm², and the contents of carbon (C), silicon (Si), manganese (Mn), titanium (Ti), and niobium (Nb) nimest united satisfy a requirement represented by formula; a protocto as a (9837) Rapidly cooling the stool platt immediatory a tartion.

of pole excandability. The cooling rate should be not, and then $x\in C$; so bacques, when the cooling rate is loss than 20°C/sec., it becomes difficult to suppress the [[8/8] 001°[8/8] 001 + [80] 0841'719 25pre extendibility {8838} Nerd, once stopping rapid cooling of the ofce a machine in the oping is incorrect for precipitating femile to increase the proportion of ferrile and to improve the .285 ≥ (20.0(2)(8/11) x (27.1) x (2 air cooling start temperature is above 800°C, the termainer of the election is recayed making it difficult to attain the effect of

[0033] The steel plate according to this sixth embodiment has both the features of the second embodiment and the applicability features of the third embodiment. Specifically, the second embodiment is effective in improving the ductility, while the third embodiment is effective in improving the bore expandability. A combination of the second embodiment with the third embodiment, however, can provide a synergistic effect on an improvement in ductility and an improvement in bore after the cooking the control of the cooking expandability. Further, when the chemical composition falls within the range represented by the above formula, the entire expandability. control of the formation of alloy, carbides advantageously, facilitates satisfying the above requirement for the grain and lease the control of the formation of the grain and lease the control of the formation of the formation of the control of the formation of enization of the structure and a reduction in the number of origins of cracks, are effective for improving the bore extense temperature. pandability. It is considered that an improvement in the former, i.e., homogenization of the structure, by the above 2008 woled formula and an improvement in the latter lieux a reduction in the number of origins of cracks, by the control of grain a solution of the number of origins of cracks by the control of grain as onused to the control of grain. diameter of fertile can provide a specific the steel plates according thill debracks and in the steel plates according this specific and in the steel plates according to the steel plates

chemical compositions with the above hot rolling conditions. Face of about the noted that, even when the steel places according to the present invendor have been subace to the present inventor have bea

vention is not lost and this embodiment does not depart from the seventh embodiment, which is a preferred embodiment of the present invention, in the steel plate having the above basic chemical composition, preferably, not less than 80% of all the grains is accounted for by PARAMELES grains having a minor axis (ds) to major axis (dl) ratio (ds/dl) of not less than 0.1, the strength is not less than 770 N/ mm², and the steel structure is a ferrite-bainite duplex structure in which the proportion of ferrite having a grain diameter of not less than 2 µm is not less than 80%, and, further, the contents of carbon (C), silicon (Si), manganese (Mn),

Steels having chemical compositions acount in the present representation of the properties (IT) multiples (IT) followed by continuous casting to produce slabs. The seasy you called not rolling conditions shown in Table At 115 \$\frac{317.480[C%]\frac{100[SI%]\frac{100[Min%]}}{200[Min%]}}\$ befor ton solutions of beloop next error one

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 $(790 \times (171\%) + (Nb\%)/2)^{0.05}) \le 235.$

[0035] The steel plate according to this seventh embodiment has all the features of the first, second, and third embodiments. Specifically, each of the first and second embodiments is effective in improving the ductility, and the third embodiment is effective in improving the bore expandability. A combination of all of these embodiments, however, can realize a synergistic effect on the improvement in ductility and the improvement in bore expandability. When the chemical composition falls within the range represented by the above formula, the control of the formation of alloy carbides advantageously facilitates satisfying the above requirements for the grain diameter of ferrite and the form of ferrite. While there is no intention of being bound by any particular theory, two measures, i.e., the homogenization of the structure and a reduction in the number of origins of cracks, are effective for improving the bore expandability. It is considered that an improvement in the former, i.e., homogenization of the structure, by the above formula and an improvement in the latter, i.e., a reduction in the number of origins of cracks, by controlling the grain diameter of ferrite and the form of ferrite can provide a synergistic effect on an improvement in bore expandability.

Production process

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[0036] The high strength hot rolled steel plates possessing excellent bore expandability and ductility according to the above embodiments of the present invention can be produced as follows. At the outset, a semi-finished steel product having the above basic chemical composition is provided according to each embodiment. This semi-finished steel product is hot rolled in such a manner that the rolling termination temperature is Ar₃ transformation temperature to 950°C, from the viewpoint of suppressing the formation of ferrite to realize good bore expandability. Subsequently, the

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hot rolled steel plate is cooled to 650 to 800°C at a cooling rate of not less than 20°C/sec. and is then air cooled for 2 - 2.1. to 15 sec. Further, the air-cooled steel plate is cooled to 350 to 600°C at a cooling rate of not less than 20°C/sec. and is then coiled. The rolling termination temperature should be Ar₃ transformation temperature or above from the viewpoint of suppressing the formation of ferrite and realizing good bore expandability. Since, however, an excessively high rolling termination temperature leads to a deterioration in strength and ductility due to coarsening of the structure, the finish Her and its 100 metrics in streeties for the first \$100 and first rolling termination temperature should be 950°C or below. [0037] Rapidly cooling the steel plate immediately after the completion of rolling is important for realizing a high level of bore expandability. The cooling rate should be not less than 20°C/sec., because, when the cooling rate is less than 20°C/sec., it becomes difficult to suppress the formation of carbides which are harmful to the bore expandability. [0038] Next, once stopping rapid cooling of the steel plate followed by air cooling is important for precipitating ferrite to increase the proportion of ferrite and to improve the ductility. When the air cooling start temperature is below 650°C, pearlite, which is harmful to bore expandability, however, is formed from an early stage. On the other hand, when the air cooling start temperature is above 800°C, the formation of ferrite is delayed making it difficult to attain the effect of air cooling. Further, in this case, the pearlite is likely to be formed in subsequent cooling. For this reason, the air cooling start temperature is between 650°C and 800°C. When the air cooling time exceeds 15 sec., an increase in the amount of ferrite is saturated and, in addition, a load is imposed on the control of subsequent cooling rate and coiling temperature. For the above reason, the air cooling time is not more than 15 sec. When the air cooling time is less than 2 sec. ferrite cannot be satisfactorily precipitated necessary construction sind reliased meaning to set neither consult of the set of the [0039] After air cooling, the steel plate is rapidly cooled again. Also in this case, the cooling rate should be not less if to learner than 20°C/sec., because; when the cooling rate is less than 20°C/sec. harmful pearlite is likely to be formed. The stop to temperature of this rapid cooling, that is, the coiling temperature, is 350 to 600° C. When the coiling temperature is 10 colors and below 350°C, hard martensite harmful to the bore exapandability is formed. On the other hand, when the colling tem! Additioning perature is above 600°C, pearlite and grain boundary cementitie harmful to the bore expandability are likely to be formed. [0040] All the steel plates according to the first to seventh embodiments can be produced by combining the above to notice chemical compositions with the above hot rolling conditions. Further, it should be noted that, even when the steel plates according to the present invention have been surface treated (for example, galvanized), the effect of the present in vention is not lost and this embodiment does not depart from the present invention.

Recording to the international and an include a present of the present

grate rewind the above base chamical nontroelium, preferency, not lace than 30% of all the grains is accounted for by (BELAMAKE) grains having a finner wite (as) to major wite (as) to recover a series and the account as a few five bound of the proportion of tentro having a grain demonstration of the second of the sec

[0041] Steels having chemical compositions shown in Table AT were produced by a melt process in a converter, followed by continuous casting to produce slabs. The slabs were rolled under hot rolling conditions shown in Table A1 and were then cooled to produce hot rolled steel plates having a thickness of 2.6 to 3.2 mm₂.

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Production process

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[0042] JIS No. 5 test pieces were extracted from the hot rolled steel plates thus obtained and were subjected to a tensile test, a bore expansion test, and observation of structure. All the grains were traced using optical photomicrographs with 30 visual fields, and, for each traced grain, the ratio (ds/dl) of the minor axis to the major axis was determined. For the bore expansion test, the bore formed by punching, having an initial bore diameter (do: 10 mm), was expanded by a 60-degree conical punch to determine the bore diameter (d) at which cracking on a level, which had passed through the plate thickness, occurred. This bore diameter (d) was used to determine and evaluate the bore expansion value (λ value) = (d - d₀)/d₀ x 100. The results are shown in Table A2..... [0043] All of Nos. A1 to A11 are examples of the present invention wherein all the chemical composition, the finishing temperature, the air cooling start temperature, and the coiling temperature fall within the scope of the present invention and, at the same time, not less than 80% of all the grains is accounted for by grains having a minor axis/major axis (ds/dl) ratio of not less than 0.1. All of these plates were high strength hot rolled steel plates having a high λ value and a high level of elongation, that is, possessing excellent bore expandability and ductility. [0044] In the case of hot rolling using a steel having a chemical composition of No. A1 under conditions of finishing temperature 920°C, air cooling start temperature 625°C, and coiling temperature 460°C, due to the air cooling start temperature below the air cooling start temperature range specified in the present invention, pearlite was formed in the structure, and the proportion of ferrite was as low as 76%. Consequently, the elongation was 20%, and the λ value was 93%, indicating that the balance between the bore expandability and the ductility was poor. Likewise, in the case of hot rolling using a steel having a chemical composition of No. A1 under conditions of finishing temperature 910°C, air cooling start temperature 690°C, and coiling temperature 330°C, due to the coiling temperature below the coiling temperature range specified in the present invention, martensite was formed in the structure, and, at the coiling temperature, the proportion of ferrite was as low as 64%. Consequently, the elongation was 20%, and the λ value was 64%, indicating that, here again, the balance between the bore expandability and the ducility was poor. Example B 100 00 [0045] Steels having chemical compositions shown in Table B1 were produced by a melt process in a converter, followed by continuous casting to produce slabs. The slabs were rolled under hot rolling conditions shown in Table B1 and were then cooled to produce hot rolled steel plates having a thickness of 2.6 to 3.2 mm. In this example, the rate of rapid cooling was 40°C/sec., and the air cooling time was 10 sec., 03 03 (1) (1) (4) Ö Ö SE1.0 BCI.0 noit 0 100 C (V 3.5

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	Tymple the rate	Proportio of ferrite,								idai W S	sf mit:	75. 12: 10:0	sta <u>d d</u> d c c c	followed by continuous casting to produc and were then cooled to produce hot roll.	
	Twiple the rate	Proportio of ferrite,	+ B 83	87	+ B 90	85	+ B 86	+ B 90	+ B 91	ਅ 66 8 +	· B 88 급 + B	94 0ilo	sia: (5 0 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2	followed by continuous casting to produc and were then cooled to produce hot roll.	
	Bunple the rate	oportio rrite,	B 83	B 87	В 90	B 85	B 86	B 90	В 91	ਦਿਸ਼: ਅ 5 6	동 등 88 B	B 84 D	85 CC #	followed by continuous casting to produc and were then cooled to produce hot roll.	
	Panple the rate	Struc- Proportio tuxe ferrite,	+ B 83	+ 8 87	+ B 90	+ B 85	+ B 86	+ B 90	+ B 91	ਅ 66 8 +	· B 88 급 + B	+ B 84 oils	sia: (5 0 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2	followed by continuous casting to product and were then cooled to produce hot roll of rapid cooling was 40°C/sec. and the	
	Grupie the rate	Struc- Proportio tuxe ferrite,	+ B 83	+ 8 87	+ B 90	F + B 85	F + B 86	F + ·B 90	8 F + B 91	ਅ 66 8 +	F + B 88 差 4 至	0 F + B 84 5 2 2 3	sia: (5 0 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2	followed by continuous casting to produce and were then cooled to produce hot roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec.	3£
	Gwn in Table C:	ue, Struc- of ture ferrite,	+ B 83	+ 8 87	+ B 90	+ B 85	+ B 86	+ B 90	+ B 91	ਅ 66 8 +	· B 88 급 + B	+ B 84 oils	sia: (5 0 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2	followed by continuous casting to produce and were then cooled to produce hot roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec.	3£
	Grup in Table C:	value, Struc- of ture farrite,	3 F + B 83	8 F + B 87	8 F + B 90	3 F + B 85	S F + B 86	2 F + B 90	8 F + B 91	S . F + B 93 A	8 子 B 号 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会	0 F + B 84 5 2 2 3	9 F + B 85 6 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	followed by continuous casting to produce and were then cooled to produce hot roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec.	3£
	Table C:	ue, Struc- of ture ferrite,	3 F + B 83	8 F + B 87	8 F + B 90	3 F + B 85	S F + B 86	2 F + B 90	8 F + B 91	S . F + B 93 A	8 子 B 号 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会	0 F + B 84 5 2 2 3	9 F + B 85 6 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec.	3£
	Emple the rate	- λ value, Struc- of of ture ferrite,	113 F + B 83	118 F + B 87	118 F + B 90	103 F + B 85	115 F + B 86	122 F + B 90	108 F + B 91	115 P + B 93 & E	118 F+B 88 差計 益	120 F + B 84 (0) 27 (2)	119 F + B 85 C 5 6 17 6 17 6 17 6 17 6 17 6 17 6 17 6	followed by continueus casting to produce and were then cooled to produce not roll of rapid cooling was 40°C/sec. and the e	3£
	Emple the rate	- λ value, Struc- of of ture ferrite,	.5 113 F + B 83	.0 118 F+B 87	118 F + B 90	.5 103 F + B 85	115 F + B 86	122 F + B 90	108 F + B 91	0 115 P + B 93 € 18	118 F+B 88 差計 益	120 F + B 84 (0) 27 (2)	119 F + B 85 C 5 6 17 6 17 6 17 6 17 6 17 6 17 6 17 6	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec. and the cooling was 40°C/sec.	3E
	Panple the rate	λ value, Struc- of ferrite,	113 F + B 83	118 F + B 87	8 F + B 90	103 F + B 85	S F + B 86	2 F + B 90	8 F + B 91	115 P + B 93 & E	8 子 B 号 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会 会	0 F + B 84 5 2 2 3	9 F + B 85 6 5 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec. and the cooling was 40°C/sec.	3E
	Environment of the fate	- λ value, Struc- of of ture ferrite,	.5 113 F + B 83	.0 118 F+B 87	118 F + B 90	.5 103 F + B 85	115 F + B 86	122 F + B 90	108 F + B 91	0 115 P + B 93 € 18	118 F+B 88 差計 益	120 F + B 84 (0) 27 (2)	119 F + B 85 C 5 6 17 6 17 6 17 6 17 6 17 6 17 6 17 6	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec. and the cooling was 40°C/sec.	3E
	Grup in Table C:	Elonga- A value, Struc- of tion, 8 % tuxe ferrite,	.5 113 F + B 83	.0 118 F+B 87	118 F + B 90	.5 103 F + B 85	115 F + B 86	122 F + B 90	108 F + B 91	0 115 P + B 93 € 18	118 F+B 88 差 4 点	120 F + B 84 (0) 27 (2)	119 F + B 85 C 5 6 17 6 17 6 17 6 17 6 17 6 17 6 17 6	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec. and the cooling was 40°C/sec.	3.5
	Grup in Table C:	le Elonga- λ value, Struc- of of tion, % % ture ferrite,	23.5 113 F + B 83	24.0 118 F + B 87	18.0 118 F + B 90	24.5 103 F + B 85	17.0 115 F + B 86	22.0 122 F + B 90	15.0 108 F + B 91	24.0 115 F + B 93 & : D	환 등 등 88 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등	24.0 120 F + B 84 E 5 X	23.5 119 F + B 85 0 5 m m	followed by continueus casting to produce and were then cooled to produce hot roll of rapid cooling was 40°C/sec. and the end of rapid cooling was 40°C/sec. and the end of rapid cooling was 40°C/sec.	3E
	Grun in Table C:	le Elonga- λ value, Struc- of of tion, % % ture ferrite,	.5 113 F + B 83	.0 118 F+B 87	118 F + B 90	.5 103 F + B 85	115 F + B 86	122 F + B 90	108 F + B 91	0 115 P + B 93 € 18	118 F+B 88 差 4 点	120 F + B 84 (0) 27 (2)	119 F + B 85 C 5 6 17 6 17 6 17 6 17 6 17 6 17 6 17 6	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the cooling was 40°C/sec. and the cooling was 40°C/sec.	3.5
	Emple the rate	- λ value, Struc- of of ture ferrite,	23.5 113 F + B 83	24.0 118 F + B 87	18.0 118 F + B 90	24.5 103 F + B 85	17.0 115 F + B 86	22.0 122 F + B 90	15.0 108 F + B 91	24.0 115 F + B 93 & : D	환 등 등 88 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등	24.0 120 F + B 84 E 5 X	23.5 119 F + B 85 0 5 m m	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the and the and the cooling was a cooling was 40°C/sec. and the cooling was 40°C/sec. and the cooling was 40°C/sec.	3.5
	Enple the rate	Tensile Elonga- λ value, Struc- of N/mm tion, % %	800 23.5 113 F + B 63	793 24.0 118 F + B 87	832 18.0 118 F + B 90	783 24.5 103 F + B 85	853 17.0 115 F + B 86	717 22.0 122 F + B 90	976 15.0 108 F + B 91	782 24.0 115 F + B 93 & 1. D	825 18.0 118 F + B 88 差 性 4	782 24.0 120 F + B 84 E 7 N	794 23.5 119 F + B 85 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the and the and the cooling was a cooling was 40°C/sec. and the cooling was 40°C/sec. and the cooling was 40°C/sec.	3.5
	Environment of the rate	le Elonga- λ value, Struc- of of tion, % % ture ferrite,	23.5 113 F + B 83	24.0 118 F + B 87	18.0 118 F + B 90	24.5 103 F + B 85	17.0 115 F + B 86	22.0 122 F + B 90	15.0 108 F + B 91	24.0 115 F + B 93 & : D	환 등 등 88 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등 등	24.0 120 F + B 84 E 5 X	23.5 119 F + B 85 0 5 m m	followed by continueus casting to produce and were then cooled to produce het roll of rapid cooling was 40°C/sec. and the analysis of the cooling was 40°C/sec. and 40	3.5

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[0046] JIS No. 5 test pieces were extracted from the hot rolled steel plates thus obtained and were subjected to a tensile test, a bore expansion test, and observation of structure. For the observation of the structure, the test pieces were corroded by nital, ferrite and bainite were then identified under a scanning electron microscope, and the percentage area of ferrite having a grain diameter of not less than 2 μ m was measured by image analysis. For the bore expansion test, the bore, formed by punching, having an initial bore diameter (d₀: 10 mm), was expanded by a 60-degree conical punch to determine the bore diameter (d) at which cracking on a level, which had passed through the plate thickness, occurred. This bore diameter (d) was used to determine and evaluate the bore expansion value (λ value) = (d - d₀)/d₀ x 100. The results are shown in Table B2.

[0047] All of Nos. B1 to B11 are examples of the present invention wherein all the chemical composition, the finishing temperature, the air cooling start temperature, and the coiling temperature fall within the scope of the present invention, the structure comprises ferrite and bainite, and at the same time, the proportion of ferrite having a grain diameter of not less than 2 μ m is not less than 80%. All of these plates were high strength hot rolled steel plates having a high λ value and a high level of elongation, that is, possessing excellent bore expandability and ductility.

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[0048] In the case of hot rolling (not shown in the table) using a steel having a chemical composition of No. B1 under conditions of finishing temperature 920°C, air cooling start temperature 625°C, and coiling temperature 460°C, due to the air cooling start temperature range specified in the present invention, pearlite was formed in the structure, and the percentage area of ferrite, having a grain diameter of not less than 2 μm was as low as 75%. Consequently, the elongation was 19%, and the λ value was 95% indicating that the balance between the bore expandability and the ductility was poor. Likewise, in the case of hot rolling using a steel having a chemical composition of No. B1 under conditions of finishing temperature 910°C, air cooling start temperature 680°C, and coiling temperature 320°C, due to the coiling temperature below the coiling temperature range specified in the present invention, martensite was formed in the structure, and the percentage area of ferrite having a grain diameter of not less than 2 μm was as low as 63%. Consequently, the elongation was 20%, and the λ value was 63%, indicating that, here again, the balance between the bore expandability and the ductility was poor.

Example C

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[0049] Steels having chemical compositions shown in Table C1 were produced by a melt process in a converter, followed by continuous casting to produce slabs. The slabs were rolled under not rolling conditions shown in Table C1 and were then cooled to produce hot rolled steel plates having a thickness of 2.6 to 3.2 mm. In this example, the rate of rapid cooling was 40°C/sec., and the air cooling time was 10 sec.

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Table C1	masse	qN	P		0.030		0.030	0.030	-	0.035		0.025	0.030	n To		Sapje CS
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	Chemical	, d	9.00.0	0:007	0:006	0,006	0.007	0.008	0.007	0.006	0.007	0.006	0.007			
		M	2,00	1, 50	1.25	1.00	-1.30	1.40	1.45	-1.85	1.45	-1.05	-1.30	3 , 502 1	ranner .	
		S	1.55	3.0.90	-0.03-1.20	0-041-50-1-00	0-041-151.30	0.051.05-	5- 1.20	5- 1.35	0.06-1.20-	5 - 125	0-041-15-	t .dranarya	بـ ــــــ ا	
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Tensilo giorga A value, Struc Proportion Proportion of ferrite Proportion Obtained by Structon of Ferrite Proportion Obtained by Structon of Ferrite and Ordinates of Galdia Calculation (Aring Calculation Office)							· ·			٠.,				٠.		
Teble C2 Teble C3 Teble C2 Teble C3 Teble C2 Teble C4 Teble		Aspect No. of invention	3.	· 6	3	3	3	3 ::	e	Ю	3.	ا . ي ي	35.			
Tonsile Blonge A value, Struc- No. strength, tion, & & ture certite, & of not less than 2 C1		Value obtained by calculation formula	153,5	124.1	180.3	229.3	168.1	140.7	153.3	11575	148.5	191:5	168.0		:	:
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Tensile Blonga- A value, Struc- of ture tion, & ture tion, & ture ferrite, & ture corresponding to the ture ferrite, & ture fe	1e C2	roportion of faving grain die for not less than m. 8	•73			: : : :> :::-	ì			08		0817:7 17	83	3		
Tensile Elonge A value, Structoff ture for ture for ture for tion, 8 & ture for ture for ture for tion, 8 & ture for ture for tion, 8 & ture for tite, 8 & ture for t	Tab			_	-	-	-			:		. ;		<u>.</u>	201	12
Tensile Blonge A value, Structory at the tion, a a ture ture N/mm, tion, a a ture ture N/mm, tion, a a ture ture circum, a a a ture circum, a a a a a a a a a a a a a a a a a a a		Proportion of ferrite.		83		88	- 98	1		-	82	-	١.	4 (2)		
Tensile Elonge λ value, value			F + B	F.+.B.	F + B.	F.+-B-	l	F. + .B			٠, ,	٠.	F + B	١.	C4737 NATE	
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		Elonga- tion, &	24.0	-24-0-	-22.5-	-24.0	- 23.0		24.0	14.0			23.0	ite, B:		
		Tensile strength, .N/mm²	7.86	785	819			ĺ .	١ .			807	803	e)-F:-ferr		
		0 0 1		25	ខ	2	CS	8		83	S	C10	C11	Not		

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5	[0050] JIS No. 5 test pieces tensile test, a bore expansion punching, having an initial both bore diameter (d) at which condiameter (d) was used to determ are shown in Table C2. [0051] All of Nos. C1 to C11 temperature, the air cooling st	n tes re di racki emir emir are d	ame ng:o ne ar exan	nd obter (con a, l nd ev nples eratu	sen lo: 1 evel alua of ti	vation 0 mm white the ne prind the	n of n), w ich h ne bo eser ne co	structuras e nad p pre e nt inv oiling	xpa pass xpa enti	e. For ndecing the nsion was on was	or the d by hrou n val where ature	e bor a 60- gh th lue (7 ein all fall v	deg le pl val the vithir	ree cate:tue) =	sion conic hick (d'	test al pr ness do) com com	the inch oc do x ipos the	to control	e; for leter ed. I The the tent	mine the his bore e results
10	and, at the same time, the va $([Ti\%] + [Nb\%]/2)^{0.05})$, was be a high λ value and a high leve [0052] In the case of hot ro temperature 920°C, air coolin	etwee el of lling ng st	elon elon usin art te	gatio gatio g a si	d 23 n, th teel ratu	5.A nat is havii re 6:	pos ga 30°C	thes ses cher an	e piè sing nice d co	etes exc oll cou	weig eller mpos tem	higi it bor sition pera	e éx of N	paño paño lo. C 450	hot labil lun C, c	rojji ity ä der lue t	ed s nd d cond o th	teel uctili ditior e alr	olate ity. U is of	having finishing ling start
15	temperature below the air co the structure, and the proport was 95%, indicating that the to of hot rolling using a steel have air cooling start temperature	ion o palar ving 700°	f ferr ice b a chi C, a	ite w etwe emic	as a en t al co iling	s low he b mpo terr	as ore e sitio pera	75% expa n of ature	. Co nda No.: 330	nsed bility C1 (quen and unde due	tly, the the r cor to th	ne el ducti ditio e co	onga lity v ns o lling	tion (as r f figi tem	was oogr. shijn pera	219 Like ter ture	o, an ewis nper belg	d the e, in atur w,th	e λ value the case e 900°C, ie colling
20	temperature range specified ferrite was as low as 65%. C again, the balance between t [0053] Fig. 3 is a diagram s steel plates having a tensile st	onse he bo how reng	que re e ing t th of	ntly, xpar he ba 770	the- dab aland to 82	elone lity : e be 0 N/	gatio and t etwe mm²	h withe centre	as 1 lucti ne e is a	9%, lity v long ppar	and was pation ent f	the . ooor. and rom f	λ va the ig. 3	lue v λ va k, the	vas l lue f	93% or hi	ind gh s the	tren pres	ng t gth l	not rolled
25	have better elongation and λ vexcellent properties of the ste by the calculation formula to corolled steel plates having a te	els, a	etwe stre	ding en 1	toʻti 15\a	e pr	eser 35. 3 820	្នាំt inv Stee	ent I pla	ion c	ould	bệ a /n iŋ	chie	ved	by b	ringi	ng ti	ie va	lue	óbtained
30	Example D [0054] Steels having chem followed by continuous castin	ical c	omp	ਰ O ositi	ons	shov	o vn:ir	Tat	le [)1 w	/ere	: prod:	uced	وااامو	con	ditio	oce	S in	ဗိုည် a) c n in	Table D1
	and were then cooled to prod	uce	nốt r	olled	stee	el pla	tes I	haviı	ng a	thic	knes	s ôf	2. <u>ē</u> t	o 3:2	uilu	. lj'n :	his	exar	nple	1
35	and were then cooled to prod of rapid cooling was 40°C/sec	uce	nốt r	olled	stee	el pla	tes I	haviı	ng a	thic	knes	s ôf	2. <u>6</u> t	0 3:2	o i	. [ji	hįs . o	exar	nple	
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[0055] JIS No. 5 test pieces were extracted from the hot rolled steel plates thus obtained and were subjected to a tensile test, a bore expansion test, and observation of structure. For the bore expansion test, the bore, formed by punching, having an initial bore diameter (d₀: 10 mm), was expanded by a 60-degree conical punch to determine the bore diameter (d) at which cracking on a level, which had passed through the plate thickness, occurred. This bore diameter (d) was used to determine and evaluate the bore expansion value (λ value) = (d - d₀)/d₀ x 100. The results are shown in Table D2.

Example E (comparative example)

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[0056] Steels having chemical compositions shown in Table E1 were produced by a melt process in a converter, followed by continuous casting to produce slabs. The slabs were rolled under hot rolling conditions shown in Table E1 and were then cooled to produce hot rolled steel plates having a thickness of 2.6 to 3.2 mm. In this example, the rate of rapid cooling was 40°C/sec., and the air cooling time was 10 sec.

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	Classifi- cation	Comparative.	Comparative	Comparative	Comparative	Comparative	Comparative	Comparative	Comparative	Comparative.	Comparative-			
	Value obtained by calculation formula	*72.1	*85.3	* *31.8	*84.1	*77.8	460.7	*80.7	9.69*	472:8	74.1	• • • • • • • • • • • • • • • • • • • •		•
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Table 52	Proportion of ferrite having grain diameter of not less than 2 µm. 8	PP#	7. C	91.	* 99*	*32	*39	ile.			91=	549T 85		
Tab	Proportion havi of of n	82	81	. [4.78.	662	7,8,7	. 7 19,67			- 80			arun holdica	17.
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[0057] JIS No. 5 test pieces were extracted from the hot rolled steel plates thus obtained and were subjected to a tensile test, a bore expansion test, and observation of structure. For the bore expansion test, the bore, formed by punching, having an initial bore diameter (do: 10 mm), was expanded by a 60-degree conical punch to determine the bore diameter (d) at which cracking on a level, which had passed through the plate thickness, occurred. This bore diameter (d) was used to determine and evaluate the bore expansion value (λ value) = $(d - d_0)/d_0 \times 100$. The results are shown in Table E2.

[0058] As is apparent from Table E2, for Nos. E1 to E10, which are comparative examples and do not satisfy requirements specified in the present invention, the balance among the strength, the bore expandability, and the ductility was poór.

[0059] As described above, according to the present invention, high strength hot rolled steel plates, which have a combination of high strength, i.e., a tensile strength of not less than 690 N/mm², with good bore expandability and ductility, can be provided in a cost-effective manner. Therefore, the high strength hot rolled steel plates of the present invention are suitable as high strength hot rolled steel plates having high workability. Further, the high strength hot rolled steel plates of the present invention can realize a reduction in weight of car bodies, one-piece molding of components, and the rationalization of a working process and, at the same time, can realize improved fuel consumption and reduced production cost and thus are highly valuable from the viewpoint of industry.

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Claims

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A process for producing the high strength hat rolled treat have a excellent bore expandability and ducility

to estate off orders that a second blaz. Not a smisle to end you at phibroces. A high strength hot rolled steel plate having excellent bore expandability and ductility, comprising a steel comprising, by mass, 0.01 to 0.15% of carbon; 0.30 to 2.00% of silicon; 0.50 to 3.00% of manganese; phosphorus ≤ 0.03%; due to 1.00% of silicon; 0.00 to 3.00% of manganese; phosphorus ≤ 0.03%; due to 1.00% of silicon; 0.00% of silicon; 0.00% of silicon; 0.00% of manganese; phosphorus ≤ 0.03%; due to 1.00% of silicon; 0.00% of s to 800°C at a cooling rate of not less than 20°C at a cooling take of not considered the state of the state

axis (dl) of not less than 0.1, said steel plate having a steel structure comprising not less than 80% of ferrite and the balance consisting of bainite, said steel plate having a strength of not less than 690 N/mm².

- The steel plate according to claim 1, wherein the steel structure is a ferrite-bainite duplex structure in which the proportion of ferrite having a grain diameter of not less than 2 µm is not less than 80%.
- 3. The high strength hot rolled steel plate having excellent bore expandability and ductility according to claim 1 or 2, wherein the contents of carbon (C), silicon (Si), manganese (Mn), titanium (Ti), and niobium (Nb) satisfy a requirement represented by formula

115 ≤ (917 - 480 [C%] + 100 [Si%] - 100 [Mn%]) -

 $(790 \times ([Ti\%] + [Nb\%V2)^{0.05}) \le 235$

and said strength is not less than 770 N/mm2.

4. A high strength hot rolled steel plate having excellent bore expandability and ductility, comprising, by mass, 0.01 to 0.15% of carbon; 0.30 to 2.00% of silicon; 0.50 to 3.00% of manganese; phosphorus \leq 0.03%; sulfur \leq 0.005%; 0.01 to 0.50% of titanium and/or 0.01 to 0.05% of niobium; and the balance consisting of iron and unavoidable impurities,

said steel plate having a ferrite-bainite duplex steel structure, in which the proportion of ferrite having a grain diameter of not less than 2 µm is not less than 80%, said steel plate having a strength of not less than 690 N/mm².

5. The steel plate according to claim 4, wherein the contents of carbon (C), silicon (Si), manganese (Mn), titanium (Ti), and niobium (Nb) satisfy a requirement represented by formula

 $115 \le (917 - 480 [C\%] + 100 [Si\%] - 100 [Mn\%]) -$

 $(790 \times ([Ti\%] + [Nb\%]/2)^{0.05}) \le 235$

and said strength is not less than 770 N/mm².

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6. A high strength hot rolled steel plate having excellent bore expandability and ductility, comprising a steel comprising, by mass, 0.01 to 0.15% of carbon; 0.30 to 2.00% of silicon; 0.50 to 3.00% of manganese; phosphorus ≤ 0.03%; sulfur ≤ 0.005%; 0.01 to 0.50% of itanium and/or 0.01 to 0.05% of nioblum; and the balance consisting of iron and unavoldable impurities, the contents of carbon (C); silicon (Si), manganese (Mn), titanium (Ti), and nioblum (Nb) satisfying a requirement represented by formula

2 6 6 mb 2 1 26 6 115 ≤ (917 - 480 [C%] + 100 [Si%]±100 [Mn%]):- 130 190 20 m 250 0 m

and an interest the two this is a larger than the case of the case in the contract of a field of the

said steel plate having a steel structure comprising not less than 80% of ferrite and the balance consisting of balance said steel plate having a strength of not less than 770 N/mm².

7. The high strength hot rolled steel plate having excellent bore expandability and ductility according to any one of claims 1 to 6, which further comprises 0.0005 to 0.01% of at least one member selected from calcium and rare earth elements (REMs).

8. A process for producing the high strength hot rolled steel plate having excellent bore expandability and ductility according to any one of claims 1 to 7, said process comprising the steps of:
அள்ளையுள்ள நடிகளை நடிகளையாக முன்னையுள்ள முன்னையுள்ளையின்றன்.

subjecting the steel having said chemical composition to hot rolling in such a manner that the rolling termination temperature is Ar₃ transformation temperature to 950°C; subsequently cooling the hot rolled steel plate to 650° to 800°C at a cooling rate of not less than 20°C/sec.; then air-cooling the steel plate for 2 to 15 sec.; further cooling the steel plate to 350 to 600°C at a cooling rate of not less than 20°C/sec.; and colling the steel plate.

The steet plate according to disimit, wherem the steet structure is a familia-behing cyclex structure in which the
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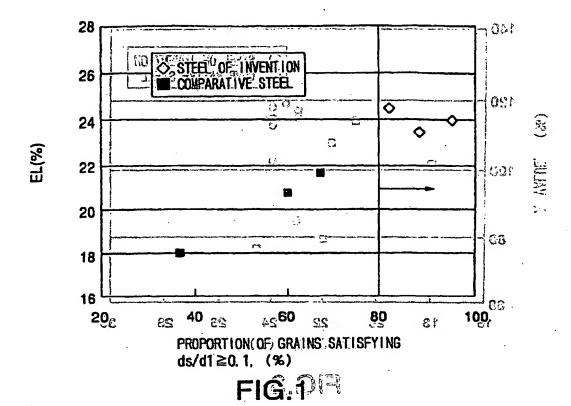
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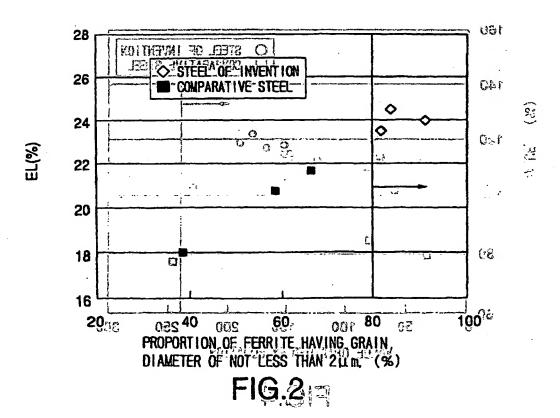
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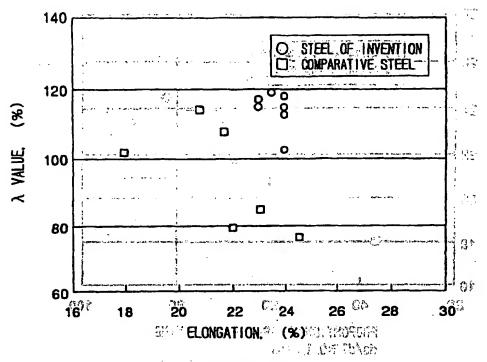


FIG.3

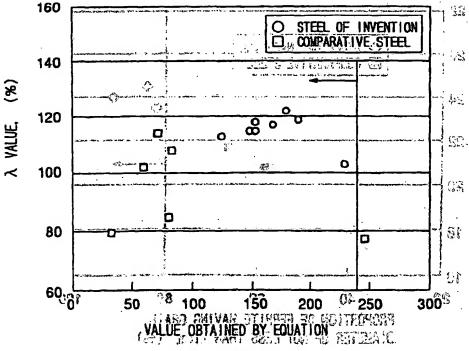


FIG.4

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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER Int.Cl? C22C 38/00, 301, C21D 9/46							
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B. FIELDS SEARCHED							
Minimum documentation searched (classification system followed Int.Cl ⁷ C22C 38/00, 301, C21D 9/46							
Documentation searched other than minimum documentation to the Jitsuyo Shinan Koho 1926-1996 Kokai Jitsuyo Shinan Koho 1971-2002	Toroku Jitsuyo Shinan Koh	D 1994-2002					
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C. DOCUMENTS CONSIDERED TO BE RELEVANT	and the constitution of the state of the sta	- comment of the					
Category* Citation of document, with indication, where ap		Relevant to claim No.					
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Further documents are listed in the continuation of Box C.	See patent family annex.						
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considered to be of particular relevance "B" earlier document but published on or after the international filing	sidered to be of particular relevance understand the principle or theory underlying the invention						
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Date of the actual completion of the international search 15 Pebruary, 2002 (15.02.02)	Date of mailing of the international search 26 February, 2002 (26						
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International application No.

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